An interesting example concerns the interpretation of beam c(660 nm) data in terms of suspended particulate matter (SPM), particulate organic carbon (POC), and primary productivity (e.g., Siegel et al., 1989). Bishop (1999) conducted a series of experiments to ascertain relations between beam c(660 nm) and SPM and POC. He determined that considerably more robust relations (r^2 of 0.9 and greater) existed between beam c(660 nm) and POC than between beam c(660 nm) and SPM. This result is quite surprising considering the large number of interpretive complications described in Section 4.1. Nonetheless, the potential use of beam c to estimate POC is important, as POC is of direct importance for the carbon cycling and flux problem.

Commercial development of sensitive kinetic fluorometers capable of deriving photosynthetic rates and parameters in real time has dramatically altered our ability to understand how photobiological processes interact with physical processes. Such instrumentation can be adapted to a wide suite of oceanographic issues, such as nutrient limitation, photoinhibition of photosynthesis, species selection, and in situ primary production. Such instrumentation, based on the fast-repetition-rate fluorescence technique (Kolber et al., 1998), has been used to follow changes in photosynthetic solar energy conversion efficiency as a function of advection (Kolber et al., 1990), and nutrient stress (Falkowski, 1992).

Presently, most bio-optical sensors are deployed from ship-based profilers and to a lesser extent from moorings. With advances in microprocessor technologies, data processing and storage are not generally limiting. The need to expand the spatial and temporal ranges and resolutions of multidisciplinary in situ observations will require utilization of more autonomous platforms such as moorings, drifters, floats, gliders, and autonomous underwater vehicles (AUVs). Capabilities of all of these platforms are improving rapidly and their costs are decreasing. Remote sensing of ocean color is also advancing, with more satellites with higher spectral and spatial resolution (e.g., Davis et al., 1999; IOCCG, 1999). Near real-time data telemetry of optical and physical data is important for many applications. Telemetry technologies are improving rapidly with new communication systems, which can be either satellite or land-based (Dickey et al., 1993b). With increased numbers of low-earth-orbit (LEO) communication satellites, we can expect increased bandwidth and more frequent data transmissions.

Many of our examples have illustrated the complexity of the ocean ecosystem, including examples of the patchy and episodic nature of phytoplankton and bio-optical properties. The applications of moored fluorometers and other optical sensors represent the biological and optical equivalents of current meters, allowing high-frequency, long-time series of chlorophyll fluorescence and light properties to be obtained from multiple locations. These data suggest that phytoplankton distributions in the ocean are not “chaotic” in a mathematical sense but are also not easily predicted (Ascioti et al., 1993). There is clearly a great need for careful work to analyze and interpret the burgeoning optical data sets. A challenge for the future will be to understand and formulate the mathematical rules by which solar radiation and biological processes are coupled through physical forcing in the ocean.

On longer temporal and spatial scales, it is critical to examine whether Earth is a unique terrestrial planet or whether other planets in neighboring solar systems have liquid water on their surface. As life on this planet has been related directly to solar energy and its major electron source (water), so must we question whether our energy sources and sinks have been replicated elsewhere. This problem, namely how solar